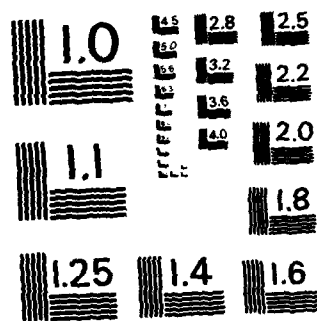


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MERRIMACK RIVER BASIN
WESTFORD, MASSACHUSETTS

MURRAY PRINTING COMPANY DAM
MA 00130

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

APRIL, 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) → The dam consists of a stone masonry main spillway with flashboards and an adjacent canal inlet structure. The 76 ft, long dam has a main spillway about 40 ft, in length. The maximum height of the dam is estimated to be 9.3 ft. The dam is confirmed to have a "significant" hazard potential. The dam is said to be in good condition. The test flood for this dam is 1/2 the PMF.		



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED

AUG 02 1979

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts 02133

Dear Governor King:

I am forwarding to you a copy of the Murray Printing Company Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. This report is presented for your use and is based upon a visual inspection, a review of the past performance and a brief hydrological study of the dam. A brief assessment is included at the beginning of the report. I have approved the report and support the findings and recommendations described in Section 7 and ask that you keep me informed of the actions taken to implement them. This follow-up action is a vitally important part of this program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. In addition, a copy of the report has also been furnished the owner, Murray Printing Company, Westford, Massachusetts 01886.

Copies of this report will be made available to the public, upon request, by this office under the Freedom of Information Act. In the case of this report the release date will be thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for your cooperation in carrying out this program.

Sincerely yours,

Max B. Scheider

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

Incl
As stated

MERRIMACK RIVER BASIN
WESTFORD, MASSACHUSETTS



MURRAY PRINTING COMPANY DAM

MA 00130

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PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

APRIL 1979

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM

Identification No.: MA 00130
Name of Dam: Murray Printing Company
Town: Westford
County: Middlesex
State: Massachusetts
Stream: Stony Brook
Date of Site Visit: 8 March 1979

BRIEF ASSESSMENT

The dam consists of a stone masonry main spillway with flashboards and an adjacent canal inlet structure. The 76 ft. long dam has a main spillway about 40 ft. in length. The maximum height of the dam is estimated to be 9.3 ft. There is no low-level outlet. Water diverted into the canal is controlled by three slide gates on the upstream side of the canal inlet structure with inverts about 7.2 ft. below the top of the dam. An approximately 200 ft. long earth embankment separates a portion of the canal from the downstream channel. A 12.7 ft. long ungated overflow spillway in the embankment can discharge water into the downstream channel only when the water level in the canal is at least 1.8 ft. higher than the main spillway crest. The dam was probably built around 1910. It presently provides cooling water for the printing company and maintains the level in Forge Pond for recreational purposes.

Due to the extent of downstream development that would be affected in the event the dam were to fail, Murray Printing Company Dam is confirmed as having a "significant" hazard potential in accordance with Corps of Engineers guidelines.

The visible portions of the dam appear to be in good condition, based on the examination of the structure. However, the overall condition of the dam can only be considered fair because the condition of the main spillway structure was obscured by water flow and there is no low-level reservoir drain. No evidence of settlement, lateral movement or other signs of structural failure, or other conditions which would warrant urgent remedial action were noted.

Based on the "intermediate" size and "significant" hazard potential classifications in accordance with Corps of Engineers guidelines, the test flood for this dam is

one-half the Probable Maximum Flood (1/2 PMF). Preliminary hydraulic analyses indicate that 4,650 cfs of the test flood outflow of 7,200 cfs (inflow 16,650 cfs or 700 csm) would be diverted to Nashoba Brook through a natural saddle upstream of the dam, starting at a stage about 1 ft. above the main spillway crest. The remaining 2,550 cfs outflow would overtop the dam by about 5.2 ft. With the water level at the top of dam, the total spillway capacity without flashboards is about 1,130 cfs, which is 44 percent of the test flood outflow at the dam site and only 16 percent of the total test flood outflow.

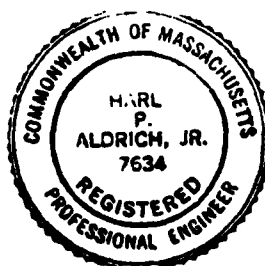
The Murray Printing Company, owner of the dam, should engage a registered professional engineer to examine the main spillway during a period when it is visible and assess its condition, determine the dimensions of the dam and evaluate its structural stability, and investigate methods for increasing project discharge and the feasibility of restoring the low-level outlet at the dam site, as outlined in Section 7.2.

Any necessary modifications resulting from the investigations, and remedial measures, including providing a gate or walkway for easy access to the main spillway, clearing brush and restoring grade at the abutments, and repairing an eroded area of the embankment near the Pleasant Street culvert, as outlined in Section 7.3, should be implemented by the Owner within one year after receipt of this report. The Owner should also prepare a formal operations and maintenance manual and emergency preparedness plan for the dam.

HALEY & ALDRICH, INC.
by:



Harl Aldrich
President



PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the office of Chief of Engineers, Washington, DC 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I Investigations are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the test flood is based on the estimated "probable maximum flood" for the region (greatest reasonably possible storm run-off), or a fraction thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential. Consideration of downstream flooding other than in the event of a dam failure is beyond the scope of this investigation.

The Phase I Investigation does not include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings and other items which may be needed to minimize trespass and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

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1. Overview of Murray Printing Company Dam

PHASE I INVESTIGATION REPORT
NATIONAL DAM INSPECTION PROGRAM
MURRAY PRINTING COMPANY DAM
MA 00130

SECTION 1 - PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a National Program of Dam Inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region.

Haley & Aldrich, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed were issued to Haley & Aldrich, Inc. under a letter dated 28 November 1978 from Colonel Max B. Scheider, Corps of Engineers. Contract No. DACW33-79-C-0018 has been assigned by the Corps of Engineers for this work. Camp, Dresser & McKee, Inc. was retained as consultant to Haley & Aldrich, Inc. on the structural, mechanical/electrical and hydraulic/hydrologic aspects of the Investigation.

b. Purpose of Inspection. The primary purposes of the National Dam Inspection Program are to:

1. Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

2. Encourage and prepare the states to initiate quickly effective dam safety programs for non-Federal dams.

3. To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. Murray Printing Company Dam is located across the outlet channel to the north from Forge Pond in the Forge Village section of Westford, Massachusetts, as shown on the Location Map, page vii. Flow from the dam is conveyed under Pleasant Street, through the printing company plant and into Stony Brook, a tributary to the Merrimack River. The coordinates of the dam site are N42°34.8', W71°29.3'.

b. Description of Dam and Appurtenances. The dam consists of a main spillway structure with flashboards, and an adjacent gated structure to divert water to a canal. The total length of the dam is approximately 76 ft., and its maximum height is estimated to be 9.3 ft. An approximately 200 ft. long earth embankment separates a portion of the canal from the downstream channel, thus acting as a secondary dam. An ungated spillway in this embankment is provided to discharge overflow from the canal. The general configuration of the project is shown on the Site Plan Sketch in Appendix C and on the overview photo, page vi.

The main spillway, approximately 40 ft. in length, is primarily of stone masonry construction. The broad-crested weir is divided into eight 4.4 ft. wide sections by vertical stanchions anchored to a concrete weir. One-foot high flashboards were observed at each section on 8 March 1979. The top of concrete (called top of dam) on either side of the spillway is approximately 4 ft. higher than the spillway crest. There is no low-level outlet at the dam site. The concrete pier to the left of the spillway (looking downstream) reportedly once contained an outlet. The main spillway structure is shown at a time of low flow in Photo No. 3 in Appendix C.

The concrete inlet structure right of the main spillway houses three wooden slide gates controlling flow to a water supply canal. The invert elevation of the gates is about 7.2 ft. below the top of dam. This former power canal was excavated into the natural hillside forming the right bank. A grass-covered earth embankment separates the canal from the downstream channel, Photo No. 8. The crest width varies from about 10 to 35 ft. The downstream slope is gentle, estimated to be generally flatter than 3 horizontal to 1 vertical. A 12.7 ft. long ungated concrete spillway in the embankment, Photo No. 9, has a crest elevation about 2.2 ft. below the top of dam. Water in the canal discharges over this spillway or is drawn into

the building at the downstream end, Photo No. 16.

c. Size Classification. The Murray Printing Company Dam has an estimated maximum storage of 2,550 acre-ft. at top of dam and a maximum hydraulic height of about 9.3 ft. Storage of from 1,000 to 50,000 acre-ft. classifies the dam in the "intermediate" size category, according to guidelines established by the Corps of Engineers.

d. Hazard Classification. Based on the Phase I investigation and the dam failure analysis, Section 5.1f, Murray Printing Company Dam was found to have a "significant" hazard potential, according to the Corps of Engineers Guidelines. If the dam were to fail, several occupied buildings of the Murray Printing Company and the nearby parking lots and roads would be subject to flooding. There is potential for loss of a few lives and appreciable damages to the industrial properties and public roads.

e. Ownership. The name, address and telephone number of the current owners are:

The Murray Printing Company
Westford, MA 01886
Telephone: (617) 692-6321

Prior to 1956, the Abbot Worsted Company owned the dam. Since the manufacturing plant was built in 1910 by the Abbot Worsted Company, it is likely that the dam was also built at that time.

f. Operator. Mr. Robert A. Allard, Plant Engineer, has been responsible for operation, maintenance and safety of the dam since 1977.

g. Purpose of Dam. The dam originally was used to provide water power for the adjoining mill. No hydroelectric power has been generated at the dam site since a 90 KW turbine in the plant was taken out of service in 1968. Presently, the owner only draws water for cooling processes. In addition, the dam maintains the level of Forge Pond, which is used for recreational purposes.

h. Design and Construction History. There are no design or construction records available to document when, how and by whom the original dam was built. However, it is likely that the present dam was constructed to provide power for the Abbot Worsted Company mills which were built in the year 1910.

i. Normal Operational Procedures. The pond level is controlled by the insertion and removal of flashboards at the crest of the spillway. The operator generally leaves the flashboards in place.

One of the three gates in the inlet structure to the right of the main spillway is normally left partially open to control the flow of water into a canal which, in turn, leads to the vertical turbine within the mill. Although the turbine is no longer operational, water from the raceway is used by the Murray Printing Company as cooling water for their process.

1.3 Pertinent Data

Without more specific information, all elevations reported herein are approximate and based on the assumption that the top of the broad-crested weir of the main spillway is at El. 204.0 MSL (the level of Forge Pond shown on the USGS Westford Quadrangle Map).

a. Drainage Area. The total discharge area of the Murray Printing Company dam is estimated to be 23.8 sq. mi. The area extends from Westford, Groton, and Littleton upstream into the communities of Boxborough and Harvard in Middlesex and Worcester counties, as shown on the map, page D-1. The Nashua River basin is located on the western boundary of the area. Elevation in the watershed varies from a low of about 200 ft. near Forge Pond to a high of about 610 ft. on Oak Hill in the town of Harvard, Worcester County. The majority of the area consists of woodlands of rolling hills and ponds, lakes and swamps on flat areas. A few small-size urban centers are scattered in the south and eastern fringes of the area. Homes exist along the shoreline of Forge Pond. Several highways, including Route 2 and Interstate 495, cross the drainage area.

b. Discharge at Dam Site

- | | |
|--|--|
| 1. Outlet works..... | Three gates, approx.
3.75 ft. wide by
about 7 ft. high,
at inlet to canal |
| 2. Maximum known flood at
dam site..... | 500 cfs at El. 207.2
in January 1979 with
1 ft. high flashboards
in place |
| 3. Ungated combined spillway
capacity at top of dam
(without flashboards)..... | 1,130 cfs at El. 208.0,
assuming canal gates
are open |

4. Ungated main spillway capacity at test flood pool elevation (without flashboards)..... 840*cfs at El. 213.2 (Tailwater at El. 209.6)
5. Gated spillway capacity at normal pool elevation.. Not applicable
6. Gated spillway capacity at test flood pool elevation..... Not applicable
7. Total spillway capacity at test flood pool elevation..... 840*cfs at El. 213.2
8. Total project discharge into downstream channel at test flood pool elevation..... 2,550**cfs, including flow over the banks

c. Elevation (ft. above MSL)

1. Streambed at centerline of dam..... 198.7
2. Maximum tailwater..... Unknown
3. Upstream portal invert diversion tunnel..... Not applicable
4. Recreation pool..... 205.0
5. Full flood control pool... Not applicable
6. Spillway crest (without flashboards).... 204.0 (Assumed) (with flashboards)..... 205.0
7. Design surcharge-original design..... Unknown
8. Top of dam..... 208.0
9. Test flood design surcharge..... 213.2

d. Reservoir

1. Length of maximum pool.... 5.0 mi. (Est.)
2. Length of recreation pool. 1.0 mi. (Est.)
3. Length of flood control pool..... Not applicable

* Excluding flow over banks and through canal
 ** 4,650 cfs of total test flood outflow of 7,200 cfs at El. 213.2 flows over a saddle at El. 205 upstream of the dam into the Nashoba Brook basin, based on preliminary computations

e. Storage (acre-ft.)

1. Recreation pool..... 900
2. Flood control pool..... Not applicable
3. Spillway crest..... 624
4. Top of dam..... 2,550
5. Test flood pool..... 7,600

f. Reservoir Surface (acres)

1. Recreation pool..... 270
2. Flood control pool..... Not applicable
3. Spillway crest..... 200
4. Top of dam..... 700
5. Test flood pool..... 1,300

g. Canal Embankment

1. Type..... Earth embankment
separating power
canal from down-
stream channel
2. Length..... Approx. 200 ft.
3. Height..... Approx. 12 ft. average
4. Top width..... Less than 5 ft.
5. Side slopes..... Generally flatter
than 3 horizontal
to 1 vertical
6. Zoning..... Unknown
7. Impervious core..... Unknown
8. Cutoff..... Unknown
9. Grout curtain..... Not likely
10. Other..... Embankment at least
partly natural hill-
side

h. Diversion and Regulating Tunnel. Not applicable

i. Main Spillway

1. Type..... Stone masonry
gravity overflow
structure
2. Length of weir..... Approx. 40 ft. (eight 4.4
ft. long sections between
flashboard supports yields
35.2 ft. net length)
3. Crest elevation..... Assumed 204.0 (without
flashboards)
4. Gates..... None

- 5. U/S channel..... Could not be observed
- 6. D/S channel..... Protected by stone masonry walls. Channel width is reduced from 40 ft. to about 20 ft. within a distance of about 40 ft. from the spillway

j. Canal Spillway

- 1. Type..... Ungated, concrete, gently curved overflow weir
- 2. Length of weir..... 12.7 ft.
- 3. Crest elevation..... Approx. 205.8
- 4. Gates..... None
- 5. U/S channel..... Approx. 7 ft. deep power canal
- 6. D/S channel..... Same as main spillway. Flow enters channel from side, approx. 45 ft. downstream of main spillway
- 7. General..... Discharges excess canal water to main downstream channel

k. Regulating Outlets. There are three double-stemmed, manually-operated (through rack and pinion gears) wooden gates at the inlet structure to the canal located to the right of the spillway. The gates are about 3.75 ft. wide by about 7 ft. in height and are operable. The invert level of the gates is assumed to be El. 200.8.

Two outlets are provided for water in the canal; namely the ungated overflow spillway located about 45 ft. downstream of the inlet structure and a raceway control at the turbine in the mill. Crest elevation of the overflow spillway is about 1.8 ft. above the main spillway, or approximately El. 205.8. The operator indicated that the canal can be emptied by closing the inlet gates and opening the gate of the turbine flow control. The turbine gate was closed and this operation was not demonstrated at the time of the site visit. A closed 36-in. diameter pipe was observed exiting the turbine chamber. The operator does not know the purpose of this pipe nor how or if it can be operated. The 12-in. diameter cooling pipe was also observed at the turbine chamber. This was the only pipe open and flowing.

To the left of the main spillway are the reported remains of the low-level outlet. A report by Metcalf &

Eddy Engineers of Boston, Massachusetts dated January 15, 1963, included on page B-2, indicates that the outlet contained a gate which could have been used to lower the level of the pond to the bottom of the dam. This outlet is no longer in operation, and a concrete wall has been constructed across the outlet on the downstream face. The top of this wall is painted yellow, Photos No. 2 and 12, and the upstream side of the former outlet is shown on Photo No. 4.

SECTION 2 - ENGINEERING DATA

2.1 Design Data

No design data for the original dam were located. It is likely that the dam was built around the year 1910.

2.2 Construction Data

No data concerning the original construction of the dam were disclosed.

2.3 Operation Data

The owner does not maintain any records regarding the operation of the dam. An engineering evaluation report on the dam was prepared by Metcalf & Eddy, Engineers, Boston, MA in 1963. The only other operation data disclosed was a state inspection report from 1973.

2.4 Evaluation of Data

a. Availability. A list of the engineering data available for use in preparing this report is included on page B-1. A copy of each document from the listing is also included in Appendix B.

b. Adequacy. There was a lack of engineering data available to aid in the evaluation of Murray Printing Company Dam. This Phase I assessment was therefore based primarily on visual examination, preliminary hydraulic and hydrologic computations, consideration of past performance and application of engineering judgement.

c. Validity. The information contained in the engineering data may generally be considered valid. However, the crest of the canal overflow spillway is actually about 1.8 ft. higher than that of the main spillway, not 2.4 ft. higher as stated in the Metcalf & Eddy report.

SECTION 3 - VISUAL EXAMINATION

3.1 Findings

a. General. The Phase I visual examination of the Murray Printing Company Dam was conducted on 8 March 1979. The water level was relatively high, approximately 2.2 ft. above the main spillway crest or 1.2 ft. above the flashboards and 0.4 ft. above the canal overflow spillway crest.

The overall condition of the project can only be considered fair, although the visible portions of the project were found to be in good condition. Several deficiencies, including the lack of reservoir drain, were noted.

A visual inspection check list is included in Appendix A and selected photographs of the project are given in Appendix C. The Site Plan Sketch, page C-1, shows the direction of view for each photograph.

b. Dam. The dam spans the outlet channel from Forge Pond. It consists of a main spillway structure and an adjacent gated inlet structure, as shown on the upstream and downstream sides in Photos 4 and 10, respectively. No signs of lateral movement or structural failure of the dam were observed. The following specific items were noted:

1. The view of the main spillway weir, spillway apron and individual flashboards was obscured by flowing water at the time of the site visit, Photo No. 2. The configuration of these components, viewed at a time of lower flow, is shown on Photo No. 3. The flashboards supports appear secure. Several branches are trapped in the spillway. There is no access to the main spillway through the fence at the left abutment.
2. The concrete pier left of the main spillway apparently once contained an outlet which is now completely blocked off by a concrete wall on the downstream side, Photo No. 2. The concrete appears to be in good condition. The upstream side is obscured by high water, Photo No. 4.
3. The concrete structure right of the main spillway, Photo No. 6, houses three wood gates controlling flow to the power canal. The concrete structure is in good condition, with some minor erosion observed on the upstream face.

The gates were partially submerged at the time of the site visit. The observed portions of the gate stems and mechanisms are in good condition.

4. The walkway over the main spillway, Photo No. 5, is in excellent condition. Note that the walkway boards over the flashboards are hinged for access below to manually remove the flashboards.
5. The earth abutments on either side of the dam, Photos No. 4, 5 and 6, have stone block protection on the upstream side and are covered by weeds and brush. Minor depressions were noted at the right abutment. The ground is several inches lower than the adjacent concrete at the left abutment, Photo No. 4.

c. Appurtenant Structures. The earth embankment retaining water in the canal acts as a secondary dam. The canal overflow spillway is included in this embankment. The embankment is grass-covered and mowed. No deficiencies which would warrant urgent remedial action were observed. The following specific items were noted:

1. The irregular left bank of the power canal forms the upstream side of the embankment, Photos No. 7 and 15. Stone masonry is generally visible below the water line in the canal and extends to the crest as a wall along the section from the gate structure to the overflow spillway, Photo No. 10. The bank is undercut in areas and two large trees are growing on the edge.
2. Several large trees are growing on the embankment crest and at the downstream toe, Photo No. 8. There are local irregularities in the ground surface. Erosion caused by drainage from two pipes near the entrance of the Pleasant Street culvert has occurred, Photo No. 14.
3. The concrete overflow spillway, Photos No. 3 and 9, is in good condition. However, a large tree has grown in the spillway discharge channel near the base, partially blocking flow. The stone masonry spillway walls, Photo No. 10, are in good condition.
4. There is no access to the main spillway when the canal overflow spillway is discharging.

d. Reservoir Area. Forge Pond is surrounded by heavily wooded hillsides. Dozens of homes are located along the shoreline. The Town's beach is located just upstream and at the west of the approach channel. There are homes along the right bank of the approach channel and a paved road along the left bank. The reservoir area is shown on Photo No. 11.

e. Downstream Channel. There are two channels extending from the dam site, as shown on the Site Plan Sketch, page C-1.

The canal on the south was used to convey water from the pond to the turbines in the mill for power generation. Inflow into this channel is controlled at the canal inlet with three manually-operated slide gates. When water level in this channel exceeds the crest elevation of the overflow spillway which is located on the left bank of the canal, water flows into the downstream channel of the main spillway. The crest elevation of the overflow spillway is at about 205.8, which is about 1.8 ft. higher than the crest elevation of the main spillway. This difference in elevation was reduced to 0.8 ft. with the presence of one-foot high flashboards at the main spillway.

At the time of the site visit, the water surface elevation in the pond was about 206.2, one gate was partially open and the canal spillway was overflowing by about 0.4 ft. of water. There was no discernable flow where the canal enters the plant building, Photo No. 16. The sidewalk at Pleasant Street and the left bank of the canal at two separate locations were only about a foot above the water surface, Photo No. 15, or 0.8 ft. below top of dam. The top of the canal embankment is generally about level with or just slightly lower than the top of dam.

The downstream channel from the main spillway extends from the spillway apron for about 1,200 ft. to the beginning of Stony Brook. In this reach, it passes through several culverts and open channel sections underneath the buildings and roads at the Murray Printing Company compound, as shown in Photo No. 17.

The upstream section of the channel, from the dam site to the stone masonry culvert underneath Pleasant Street (Route 225), is about 200 ft. long, Photo No. 12. Here, the channel shape is rectangular with about 17 ft. bottom width. The channel bottom gradient is quite steep at two percent. The channel walls are protected with hand-placed stone masonry. The right bank is an about 50 ft. wide earth

embankment which slopes up to the power canal. At the time of the site visit, the water depth in the downstream channel was about 2.2 ft. There were floating logs, brush and one large tree, Photo No. 13, growing in the channel. A significant bank erosion was observed at the right bank next to the culvert underneath Pleasant Street, Photos No. 13 and 14.

A schematic profile of the downstream channel is shown on page D-10 in Appendix D. The raceway from the canal joins to the downstream channel at about midpoint of its total length within the plant compound. The eastern parking lot on the left bank, Photo No. 18, is subject to flooding because of its relatively low level. At the time of the site visit, the flow in the channel was about 110 cfs, and the water surface elevation in Stony Brook was only about 2.5 ft. lower than the pavement surface. The Stony Brook channel has a bottom width of about 40 ft. at this section. During several storms in the past, the driveways and parking lots within the plant compound were flooded because of capacity restriction in the downstream channel.

3.2 Evaluation

Based on the visual observations that could be made during the site examination, the general condition of the project is good. However, the overall condition of the project can only be considered fair, primarily because the main spillway structure could not be examined. Therefore, another examination should be made at a time when there is low flow to observe the condition of the granite masonry spillway weir, the downstream apron and individual flashboards. Currently, there is no easy access to the main spillway in order to remove the flashboards in times of emergencies.

Except for the lack of reservoir drain, the deficiencies that were noted should not affect the performance of the dam during usual seasonal variations in flow. The trees growing at the canal overflow spillway channel and downstream channel impede flow, but do not directly affect the safety of the dam.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

In general, there are no formal procedures to provide routine maintenance and satisfactory operation of the dam. One canal gate is usually left partially open.

4.2 Maintenance of Dam

There are no established procedures or manuals for inspection and maintenance of the dam. Routine maintenance such as cutting the grass on the embankment is provided by the owner on an as-required basis.

4.3 Maintenance of Operating Facilities

Although there is no established maintenance program for the operation facility other than routine maintenance on a demand basis, the observed condition of the facility indicates the facility to be well maintained. The owner has installed new structural steel supports at the top of the dam to hold the flashboards in place. One gate has been rebuilt and one gate repaired in the canal inlet structure. The operator reportedly clears debris from the spillway periodically.

4.4 Description of any Warning System in Effect

There is no warning system or emergency preparedness plan in effect for this structure.

4.5 Evaluation

The owner should prepare an operations and maintenance manual for the dam. The manual should delineate the routine operational procedures and maintenance work to be done on the dam to provide satisfactory operation and minimize deterioration of the facility. An annual observation and maintenance program should be established to examine the dam, control vegetation growth and maintain slopes, walls and channels.

Since failure of the dam would probably cause loss of life and significant industrial property damage downstream, the owner should also prepare a formal emergency preparedness plan and warning system.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. General. The dam is primarily a stone masonry spillway structure with a concrete cap on the top. The original purpose of the dam and reservoir was water storage and regulation for power generation; now the reservoir is used for recreation. Flow spills over the main spillway during the wet season. Additional spillage through an overflow spillway on the side of the canal could occur if the canal inlet gates were open and the water surface elevation in the pond exceeded the crest elevation of the overflow spillway. Some water from the canal is drawn for cooling processes in the plant.

The existing swamps, lakes and ponds would have a dampening effect on the intensity of the floods during a storm. Based on a study of USGS quadrangle maps of the drainage area, it appears that water would be diverted into the adjacent Nashoba Brook basin, over a saddle along Howard Road about 1.8 mi. southeast of the dam, when the water surface level in Forge Pond exceeds about El. 205. This area was not studied in any detail in the field.

b. Design Data. No hydraulic or hydrologic design data were available for this dam site.

c. Experience Data. The maximum overflow from the spillway was recorded in January 1979. The water surface, at that time, reached El. 207.2. This was about 2.2 ft. above the 1 ft. high flashboards, which were left in place. The estimated discharge into the downstream channel was about 500 cfs, which includes 70 cfs overflow from the canal spillway (reportedly the canal inlet gates were open). A parking lot about 800 ft. downstream from Pleasant Street and several access roads within the company property were flooded during this storm.

The September 1938 flood reportedly caused a pond water surface elevation of 206.3, which corresponds to an estimated maximum flow of 450 cfs, if there were no flashboards at the crest at that time and no flow in the canal. No data is available on other historical floods.

d. Visual Observations. The approach channel to the dam is about 100 ft. wide and 800 ft. long. Within its total length of 76 ft. the dam includes an approximately 40 ft. long main spillway and a 15 ft. long gate inlet structure for the old power canal, which has an overflow type spillway on the left bank. The main

spillway is divided into eight sections, each having provisions for flashboards.

The water surface elevation in the pond during the site visit was about 1.2 ft. above the flashboards on the main spillway. One of the gates at the power canal inlet was partially open, and water about 0.4 ft. in height was flowing over the canal spillway. The water surface elevation in the canal was only about one ft. below the sidewalk on Pleasant Street; a similar freeboard existed also at two points along the earth embankment on the left bank.

The land on the right bank rises very rapidly to about a 30 ft. height near the spillway and a 15 ft. height near Pleasant Street; large residential dwellings are located in this area. The left bank, about 100 ft. wide and relatively flat, includes a fence, road to the Town beach, Boston & Maine railroad and state highway Route 225. No dwellings are located between the railroad embankment and the downstream channel until Pleasant Street. The plant buildings are located on both sides and on top of the downstream channel beyond Pleasant Street.

The canal is about 7 ft. deep from top of the left bank and about 20 ft. wide at the upstream end. Its width increases to about 50 ft. at mid-length to Pleasant Street. A staff gage attached to the wall at the culvert under Pleasant Street indicates the level of the pond, approximately, as there is only slight flow through the raceway intake.

The downstream channel walls are made of hand-placed stone masonry blocks. The channel gradient is quite steep at about 2 percent, upstream of Pleasant Street. A bank erosion was observed on the right bank near the Pleasant Street culvert. Here, stone masonry blocks of the culvert are slightly dislocated. Growth of brush and a tree and floating logs were observed in the channel.

The channel flows through several culverts underneath the driveways and through the plant buildings within its about 1,000 ft. length from Pleasant Street to the starting point of Stony Brook. Here, the channel appears to be well maintained.

e. Test Flood Analysis. Based upon the Corps of Engineers guidelines, the recommended test flood for the size "intermediate" and the hazard potential "significant" is within a range of 1/2 PMF to PMF (Probable

Maximum Flood). The PMF was determined using Corps of Engineers Guidelines for Estimating Maximum Probable Discharge in Phase I Dam Safety Investigations. The watershed terrain was determined to be rolling, and an inflow rate of 1,400 cfs per square mile was interpolated for the discharge area of 23.8 sq. mi. The resulting PMF inflow is 33,300 cfs.

The 1/2 PMF inflow of 16,650 cfs was adopted as the test flood for this investigation. Surge-storage routing was performed through Forge Pond, using the related stage-discharge and area volume curves which are shown in Appendix D. Flow through the existing power canal is assumed to be zero for this evaluation. It is also assumed that the existing 1 ft. high flashboards would be removed from the crest of the spillway.

The test flood outflow, which was estimated to be 7,200 cfs, would occur when the water surface elevation in the pond is 213.2'. This is about 5.2 ft. above the top of the dam. Assuming that about 4,650 cfs would be diverted into the adjacent Nashoba Brook basin through a saddle at El. 205 (see map, page D-1), the remaining 2,550 cfs would flow over the dam site, causing flooding of the banks. The ungated capacity of the spillways with the water at the top of the dam is approximately 1,130 cfs or 44 percent of the estimated test flood outflow at the dam site and only 16 percent of the total test flood outflow.

The diversion saddle to Nashoba Brook was not observed in the field. Therefore, the effects of the additional test flood flow to the brook could not be assessed. If less than 4,650 cfs were diverted to Nashoba Brook, the test flood outflow at the dam would further exceed the capacity of the spillways. It is apparent that neither the spillways nor the downstream channel of the Murray Printing Company Dam are adequate for the test flood flow.

f. Dam Failure Analysis. Based on Corps of Engineers Guidelines for Estimating Dam Failure Hydrographs and assuming that a failure would occur along 90 percent of the length of the dam structure, the peak failure outflow is estimated to be 2,950 cfs. The downstream channel capacity is not adequate to carry this much flow without flooding its banks. Pleasant Street would not be overtopped by the dam failure. Damage would be confined to about seven buildings of the Murray Printing Company, including the adjacent driveways and parking lots, expected to be flooded with six to seven ft. deep water. Just prior to failure, with the water level at the top of the dam, the printing company area would be flooded with about one ft. of water (see the hydraulic profiles, page D-10).

Therefore, it can be concluded that a potential for loss

of a few lives and appreciable industrial property damages exists at this dam site. Because of this, the dam is classified as having a "significant" hazard potential according to Corps of Engineers guidelines.

SECTION 6 - STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. There is no evidence that movement or distress is present in the main spillway, the canal inlet structure or the canal spillway. However, the main spillway weir was obscured by flowing water. With an observed flow of about 2.2 ft. over the main spillway crest with no movement or distress noted, the structure was considered structurally stable under the observed loading conditions during the time of the site visit.

There was no visual evidence of excessive settlement, lateral movement, seepage or other signs of structural instability in the earth embankment separating the canal and the downstream channel.

b. Design and Construction Data. No design data or construction plans were located for this dam. Since the geometry (cross-section) of the main dam is not known, it was not possible to determine its structural stability under static loading conditions. The broad, relatively flat canal embankment is expected to be stable under static loading conditions.

c. Operating Records. No operating records other than prior inspection reports were located.

d. Post-Construction Changes. Other than the construction of a concrete wall across the outlet on the left side of the dam, there are no other indications or records of any changes that may have been made to the original dam.

e. Seismic Stability. The Murray Printing Company Dam is located in a Seismic Zone 2 and in accordance with Recommended Phase I Guidelines does not warrant seismic analysis.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. The visual examination of Murray Printing Company Dam indicated that the visible portions of the structure were in good condition. However, flowing water prevented a complete examination. For this reason, the overall condition can only be considered fair at this time. Several deficiencies, including the lack of a reservoir drain, were noted. However, there were no signs of impending structural failure or other conditions which would warrant urgent remedial action.

Based on the results of computations included in Appendix D and described in Section 5, the spillway is not capable of passing the test flood, which for this structure is the 1/2 PMF. It appears that about 4,650 cfs of the test flood outflow of 7,200 cfs (inflow 16,650 cfs or 700 csm) would be diverted through a natural saddle at El. 205 upstream of the dam. The remaining 2,550 cfs outflow would overtop the dam by about 5.2 ft. With the water level at the top of the dam, the main and auxiliary spillway system can pass about 1,130 cfs, which is 44 percent of the test flood outflow at the dam site and 16 percent of the total test flood outflow.

b. Adequacy of Information. This evaluation of the dam is based primarily on visual examination, preliminary hydraulic and hydrologic computations, consideration of past performance and application of engineering judgement. Generally the information available or obtained was adequate for the purposes of a Phase I assessment. However, it is recommended that additional information regarding the condition of the spillway weir, configuration of the dam and the blocked low-level outlet be obtained, as outlined in Section 7.2.

c. Urgency. The recommendations for additional investigations and remedial measures outlined in Sections 7.2 and 7.3, respectively, should be undertaken by the Owner and completed within one year after receipt of this report. Should examination during low flow conditions indicate a "good" condition, remedial measures can be undertaken within two years.

d. Need for Additional Investigation. Additional investigations should be performed by the Owner as outlined in Section 7.2.

7.2 Recommendations

It is recommended that the Murray Printing Company, owner of the dam, engage a registered professional engineer to undertake the following investigations:

1. Examine the main spillway structure during a time of no or low flow conditions, assess its condition and determine the dimensions of various portions of the dam, in particular the main spillway. Based on this information, evaluate the structural stability of the dam.
2. Investigate methods for increasing project discharge, including further study of flow diversion to Nashoba Brook, and the feasibility of reconstructing the outlet on the left side of the spillway, which could be used to lower the water elevation behind the dam in the case of an emergency.

The Owner should then implement corrective measures on the basis of this engineering evaluation.

7.3 Remedial Measures

Although the dam appears generally in good condition, it is considered important that the following items be accomplished:

a. Operation and Maintenance Procedures. The following should be undertaken by the Owner:

1. Construct a gate in the chain link fence to the left of the main spillway of the dam or a walkway across the canal spillway for easy access to the main spillway during times of high flow and times of emergencies.
2. Clear brush and fill low areas adjacent to the concrete at both abutments of the dam to restore grade to the top of the dam.
3. Repair eroded bank and wall at toe of embankment adjacent to the Pleasant Street culvert.
4. Prepare an operations and maintenance manual for the dam. The manual should include provisions for annual technical inspection of the dam and for surveillance of the dam during periods of heavy precipitation and high reservoir levels. The procedures should delineate the routine

operational procedures and maintenance work to be done on the dam to ensure satisfactory operation and to minimize deterioration of the facility.

5. Because the dam is classified as having a "significant" hazard potential, the Owner should also develop a written emergency preparedness plan and warning system to be used in the event of impending failure of the dam. The plan should be developed in cooperation with local officials, company employees and downstream inhabitants.

7.4 Alternatives

The Owner should consider investigating the downstream controls of the turbine raceway for possible use as an emergency outlet, particularly the 36-in. diameter pipe from the turbine chamber. Presently, the operator is not familiar with using these controls and could not demonstrate their operation.

APPENDIX A - INSPECTION CHECK LIST

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<u>VISUAL INSPECTION PARTY ORGANIZATION</u>	A-1
<u>VISUAL INSPECTION CHECK LIST</u>	
Canal Embankment and Dam Abutments	A-2
Outlet Works - Spillway Weir, Approach and Discharge Channels	A-3
Outlet Works - Service Bridge	A-4
Outlet Works - Canal Inlet Structure, Canal and Overflow Spillway	A-5

VISUAL INSPECTION PARTY ORGANIZATION

NATIONAL DAM INSPECTION PROGRAM

Dam: Murray Printing Company Dam

Date: 8 March 1979

Time: 0730-1030

Weather: Cloudy, cool (40°F)

Water Surface Elevation Upstream: Approximately 2.2 ft.
above the main spillway
weir

Stream Flow: Heavy (Estimated 110 cfs)

Inspection Party:

Peter L. LeCount	-	Soils/Geology
Richard A. Brown		
Haley & Aldrich, Inc.		
A. Ulvi Gulbey	-	Hydraulic/Hydrologic
Robert P. Howard	-	Structural/Mechanical
William Kane		
Camp, Dresser & McKee, Inc.		

Present During Inspection:

Robert A. Allard, Plant Engineer
Murray Printing Company

VISUAL INSPECTION CHECK LIST **NATIONAL DAM INSPECTION PROGRAM**

DAM: Murray Printing Company

DATE: 8 Mar. 79

AREA EVALUATED	CONDITION
<p><u>CANAL EMBANKMENT AND DAM ABUTMENTS</u></p> <p>Crest Elevation</p> <p>Current Pool Elevation</p> <p>Maximum Impoundment to Date</p> <p>Surface Cracks</p> <p>Pavement Condition</p> <p>Movement of Settlement of Crest</p> <p>Lateral Movement</p> <p>Vertical Alignment</p> <p>Horizontal Alignment</p> <p>Condition at Abutment and at Concrete Structures</p> <p>Indication of Movement of Structural Items on Slopes</p> <p>Trespassing on Slopes</p> <p>Animal Burrows in Embankment</p> <p>Vegetation on Embankment</p> <p>Sloughing or Erosion of Slopes or Abutments</p> <p>Rock Slope Protection - Riprap Failures</p> <p>Unusual Movement or Cracking at or near Toes</p>	<p><u>NOTE:</u> Basically masonry dam with overflow spillway; earth embankment/natural slope between canal and downstream channel acts as a secondary dam. Notes refer to this embankment except where specific reference to dam abutment areas</p> <p>Approximately El. 208 (4 ft. above main spillway crest)</p> <p>Approximately El. 206.2 (2.2 ft. above main spillway crest)</p> <p>Unknown</p> <p>None apparent (grass)</p> <p>Not applicable</p> <p>None apparent - irregular</p> <p>None apparent - irregular</p> <p>Irregular shape</p> <p>Irregular shape</p> <p>Brush, weeds and fence at right abutment; local slight depression in grass behind stone masonry walls along top of each embankment; ground with weeds, grass and cut brush down about 1 ft. behind left abutment</p> <p>Not applicable</p> <p>None apparent; area fenced in behind abutments</p> <p>None observed</p> <p>Embankment grass-covered, several large trees on slope</p> <p>None evident</p> <p>Water high, exposed masonry appears intact</p> <p>Not observed</p>

FILE NO. 4160

VISUAL INSPECTION CHECK LIST **NATIONAL DAM INSPECTION PROGRAM**

DAM: Murray Printing Company **DATE:** 8 Mar. 79

AREA EVALUATED	CONDITION
Unusual Embankment or Downstream Seepage Piping or Boils Foundation Drainage Features Toe Drains Instrumentation Systems	Not observed Not observed None known None known None known
<u>OUTLET WORKS - SPILLWAY</u> <u>WEIR, APPROACH AND</u> <u>DISCHARGE CHANNELS</u>	
<u>a. Approach Channel</u>	
General Condition Loose Rock Overhanging Channel Trees Overhanging Channel Floor of Approach Channel	Good None observed Some trees overhanging right side of channel Submerged-not observable
<u>b. Weir and Training Wall</u>	
General Condition of Concrete	Very heavy sheet flow over the crest. Condition of the spillway and flashboards not observable. Remains of an outlet to left of spillway has been blocked with a concrete wall at the face of dam in good condition. Granite masonry training walls in good condition. Some minor spalling of joints on left wall near drain
Lateral Movement Vertical Alignment Horizontal Alignment Condition at Abutment and at Concrete Structures Rusting or Staining Spalling Any Visible Reinforcing	None observed Good Good Good Minor staining observed None observed None observed

VISUAL INSPECTION CHECK LIST **NATIONAL DAM INSPECTION PROGRAM**

DAM: Murray Printing Company

DATE 8 Mar. 79

AREA EVALUATED	CONDITION
Any Seepage or Efflorescence	None observed
Drain Holes	None observed
<u>c. Discharge Channel</u>	
General Condition	Good
Loose Rock Overhanging Channel	None observed
Trees Overhanging Channel	Overhanging trees on right bank
Floor of Channel	None observed
Other Obstructions	Brush growth at left side near drain. Tree in channel near Pleasant Street culvert
<u>OUTLET WORKS - SERVICE BRIDGE</u>	
<u>a. Super Structure</u>	
Condition	Walkway and incorporated flashboard supports in excellent condition
Anchor Bolts	Good
Bridge Seat	Good
Longitudinal Members	Excellent
Under Side of Deck	Not applicable
Secondary Bracing	Excellent
Deck	Wooden plant deck-excellent condition
Drainage System	Not applicable
Railings	Excellent
Expansion Joints	None observed
Paint	Excellent
<u>OUTLET WORKS - CANAL INLET STRUCTURE, CANAL AND OVERFLOW SPILLWAY</u>	
<u>a. Canal Inlet Structure</u>	
General Condition of Concrete Inlet Structure	Good
Rust or Staining	Minor staining observed
Spalling	Minor spalling observed
Erosion or Cavitation	Minor erosion of concrete on upstream face of water line

VISUAL INSPECTION CHECK LIST **NATIONAL DAM INSPECTION PROGRAM**

DAM: Murray Printing Company DATE: 8 Mar. 79

AREA EVALUATED	CONDITION
<p>Visible Reinforcing Any Seepage or Efflorescence Condition at Joints Drain Holes</p>	<p>None observed None observed Good None observed</p>
<p>b. <u>Canal</u></p> <p>Channel Loose Rock or Trees Overhanging Channel Condition at Discharge Channel</p>	<p>Submerged - not visible Trees overhanging both banks Submerged - not visible</p>
<p>c. <u>Overflow Spillway</u></p> <p>General Conditions of Structure Spillway Walls Obstructions</p>	<p>Good Stone masonry walls in good condition Tree in middle of spillway channel, partially blocking flow</p>

APPENDIX B - ENGINEERING DATA

	<u>Page</u>
<u>LIST OF AVAILABLE DATA</u>	B-1

PRIOR INSPECTION REPORTS

<u>Date</u>	<u>By</u>	
15 January 1963	Metcalf & Eddy, Engineers	B-2
11 October 1973	Mass. Dept. of Environmental Quality Engineering	B-5

DRAWINGS

None available

LIST OF AVAILABLE DATA
MURRAY PRINTING COMPANY DAM

<u>Document</u>	<u>Contents</u>	<u>Location</u>
Report upon Murray Printing Company Dam, Metcalf & Eddy, Engineers, Boston, MA, 15 January 1963	Engineering report including general conclusions and recommendations, spillway capacity and flood flows and condition and repair information	Mass. Department of Environmental Quality Engineering, Division of Waterways, 100 Nashua Street, Boston, MA 02114 (and page B-2)
State inspection report dated 11 October 1973	Only state inspection report on file. Includes description of dam	Mass. Department of Environmental Quality Engineering (and page B-5)

METCALF & EDDY
Engineers
Boston, Massachusetts

JSK:eg
1/15/63

Report
upon
Murray Printing Company Dam
Westford, Massachusetts

General

The Murray Printing Company Dam across Stony Brook is located in the Forge Village section of Westford, Massachusetts. The structure is primarily of stone masonry construction. A major portion of the structure is the main spillway.

The purpose of the dam is to provide water power for the adjoining mill and to raise the level of Forge Pond which is used for recreational purposes.

The structure has a total length of about 76 ft. and a height of about 8.5 ft.

Three gates at the southerly end of the structure control the flow of water into a canal which leads to the power house of the mill. A section of the canal has a built-up earth embankment along one side, and the remainder is sectioned out from a hillside.

There are two spillways. The main spillway is a broad crested type about 4 ft. deep and 44.5 ft. long and is divided into eight sections. Each section has provision for stop logs. To the north of the main spillway is a small bay which previously contained a gate which was used for lowering the level of the pond to the bottom of the dam.

A second spillway is located on the northerly side of the canal about 45 ft. downstream from the centerline of the main structure. The crest elevation of this spillway is about 2.4 ft. higher than that of the main spillway. This secondary spillway will be an aid in the relief of flood flows of major proportion providing that the gates leading to the canal are open.

Conclusions and Recommendations

1. When allowance is made for the effect of storage in the swamps and ponds on the watershed, the combined discharge capacity of the spillways is about 40 percent of the expected Rare Flood Flow based on the Kinnison-Colby Formula.
2. The spillway capacity should be increased to discharge the Rare Flood Flow by a method approved by the County Commissioner.
3. The stop logs should be removed whenever there is a danger of a flood or hurricane.
4. All plans for the repair and reconstruction of the dam should first be approved by the County Commissioner and all work done should be inspected by the Commissioner.

Spillway Capacity and Flood Flows

The discharge capacity of the main spillway with the stop logs removed is about 1,170 cfs. (cubic feet per second) and that of the canal spillway is about 88 cfs. The combined discharge capacity is therefore, about 1,258 cfs.

The total drainage area above the dam is about 24.6 square miles. The maximum flood flow as estimated from the Kinnison-Colby Formula (Rare Floods) is about 4,860 cfs. To arrive at the above flood flow, it is assumed that the flood flow from dam K-7 reaches the spillway at the same time as the flow from the rest of the drainage area.

There are swamps and ponds on some sections of the drainage area. These will store some of the flood waters of the drainage area thereby reducing the magnitude of the flood flow. The actual flood flow at the dam has, therefore, been estimated as 3,000 cfs.

In order for the spillway to discharge a flood flow of 3,000 cfs., the crest of the canal spillway could be lowered to equal the level of the crest of the main spillway, and the overall length increased to about 70 ft. Another method for increasing spillway capacity would be to lower the crest elevation of both spillways.

K-4
3

Condition and Repairs

The stability of the dam appears adequate and its condition appears to be good.

Only minor leakage was noted.

The only maintenance that appeared necessary at this time was to fill in a small depression in the earth embankment on one side of the canal spillway.

Charles E. Cannon
Charles E. Cannon
Project Engineer

INSPECTION REPORT - DAMS AND RESERVOIRS

(1.) Location: State/Town WESTFORD Dam No. 4-9-330-1
 Name of Dam MURRAY PRINTING CO. DAM Inspected by A.Z. PIZANY
F.H. PARE
 Date of Inspection 10-11-73

(2) Owners: Part: Assessors ☒ Prev. Inspection
Reg. of Deeds Pers. Contact

1. MURRAY PRINTING CO. FORGE VILLAGE, WESTFORD, MASS 01886 (692-6321)

Name St. & No. City/Town State Tel. No.

2. Name St. & No. City/Town State Tel. No.

3. Name St. & No. City/Town State Tel. No.

(3) Caretaker (if any) e.g. superintendent, plant manager, appointed by
 absentee owner, appointed by multi owners.

MR. G.A. RADIER, PLANT MGR., MURRAY PRINTING CO. - 01886 (692-6321)
 Name St. & No. City/Town State Tel. No.

(4) No. of Pictures taken 3

(5) Degree of Hazard: (If dam should fail completely)
 1. Minor ☒ 2. Moderate
 3. Severe 4. Disastrous

*This rating may change as land use changes (future development)

(6) Outlet Control: Automatic Manual ☒
 Operative ☒ Test:

Comments: FLASH BOARDS, MANUALLY OPERATED, CONTROL SPILLWAY.

AUTOMATIC FLOOD GATE, CONTROLLED BY RATCHET OPERATION OF
METAL PLATE, USED ONCE A YEAR TO CLEAN CHANNEL ON ONE EMERGENCY
SPILLWAY. OTHER EMERGENCY
SPILLWAY CLOSED, AND NOT USED.

(7) Spillway Part of Dam:

In. Section:

 ☒

-2-

DAM NO. 4-9-330-1

(8) Downstream Face of Dam: Condition: 1. Good ☒ 2. Minor Repairs ☐
3. Major Repairs ☐ 4. Urgent Repairs ☐

Comments: _____

(9) Emergency Spillway: Condition: 1. Good ☒ 2. Minor Repairs ☐
3. Major Repairs ☐ 4. Urgent Repairs ☐

Comments: _____

(10) Water level @ time of inspection _____ ft. above 0.5' below _____
top of dam _____ Principal spillway ☒
other _____

(11) Summary of Deficiencies Noted: NONE NOTED.

Growth (Trees and Brush) on Embankment _____
Animal Burrows and Washouts _____
Damage to slopes or top of dam _____
Cracked or Damaged Masonry _____
Evidence of Seepage _____
Evidence of Piping _____
Erosion _____
Leaks _____
Trash and/or debris impeding flow _____
Clogged or blocked spillway _____
Other _____

(22) Remarks & Recommendations: (Fully Explain)

DAM IS IN GOOD CONDITION.

(13) Overall Condition:

1. Safe ☒
2. Minor repairs needed _____
3. Conditionally safe - major repairs needed _____
4. Unsafe _____
5. Reservoir impoundment no longer exists (explain)
Recommend removal from inspection list _____

DESCRIPTION OF DAM
DISTRICT # 4

Submitted by ADAM Z. PIZAN, FRANCIS H. PARÉ &
Date 10-11-73 A. Z. PIZAN

Dam No. 4-9-330-1
City/Town WESTFORD
Name of Dam MURRAY PRINTING CO. DAM

Location: Topo Sheet No. 25 C
Provide 8 1/2" x 11" in clear copy of topo map with location of Dam

Year built: 1910 Year/s of subsequent repairs EVERY YR (JULY)
CHANNEL CLEANED

Purpose of Dam: Water Supply Recreational? ✓
Irrigation Other

Drainage Area: 4.5 sq. mi. 2880 ACRES.

Normal Ponding Area: 150 acres; Ave Depth 5'
impoundment: 250 MIL. GALS; 750 acre ft.

No. and type of dwellings located adjacent to pond or reservoir
summer homes of 13 HOMES, 1 GAS STATION & 1 RESTAURANT

Dimensions of Dam: Length 48' Max. Height 5' DEPTH 12 BOARDS
Slopes: Upstream face VERT.
Downstream Face VERT.
Width across top 2" (2" x 12" FLASH BOARDS)

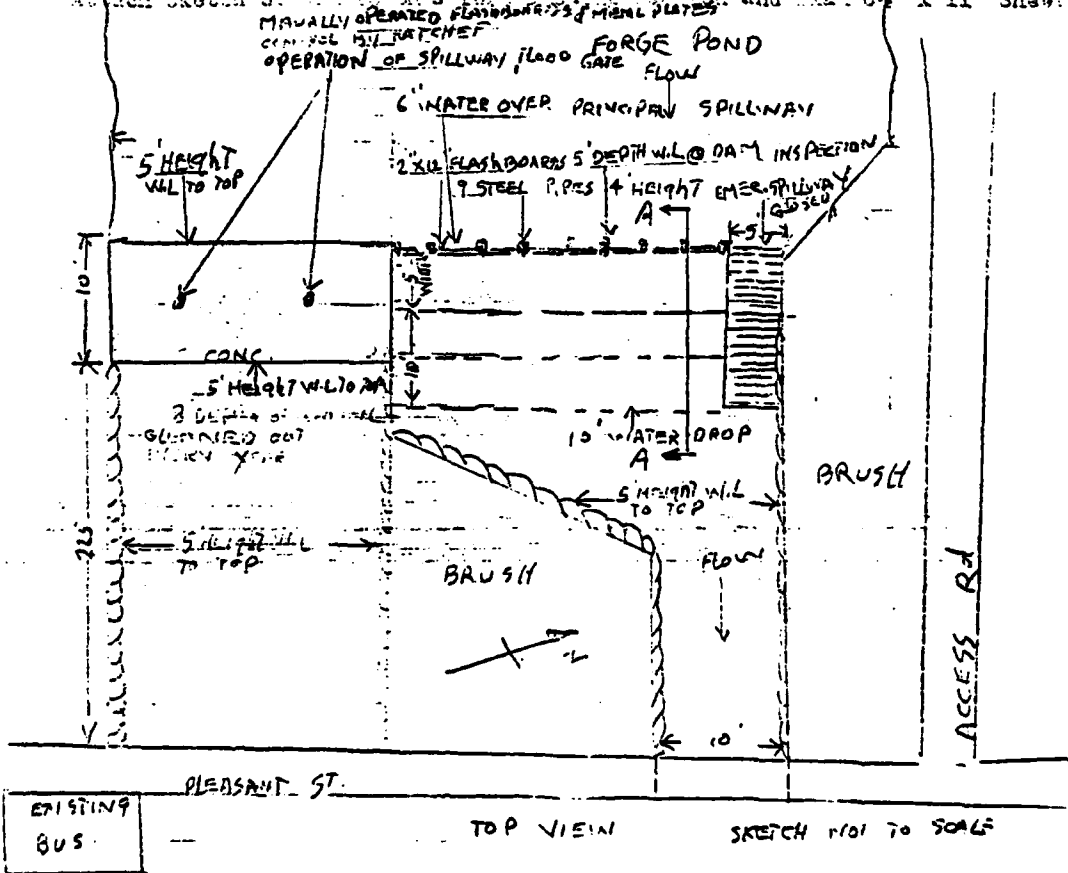
Classifications of Dam by Material:
Earth Conc. Masonry ✓ Stone Masonry ✓
Timber Rockfill Other

Description of present land use downstream of dam 80% rural;
20% urban
Is there a storage pond or flow plant downstream? no which could
accommodate the impoundment in the event of a crop or fish failure
no

4-9-330-

140 EST. PER BUSINESS
CL. 100000
CG SARGENT'S SON, BRADMAN ST. WESTFORD
NAME
No. of utilization
Railroads 1 OPERATING
Other dams 1 APPROX. 13 MILES DOWNSTREAM 7 STONY BROOK DAM
Other GRANITVILLE LEARN 4-7-33-3

Attach sketch of part to this form showing location and size. 8 1/2" x 11" Sheet



APPENDIX C - PHOTOGRAPHS

LOCATION PLAN

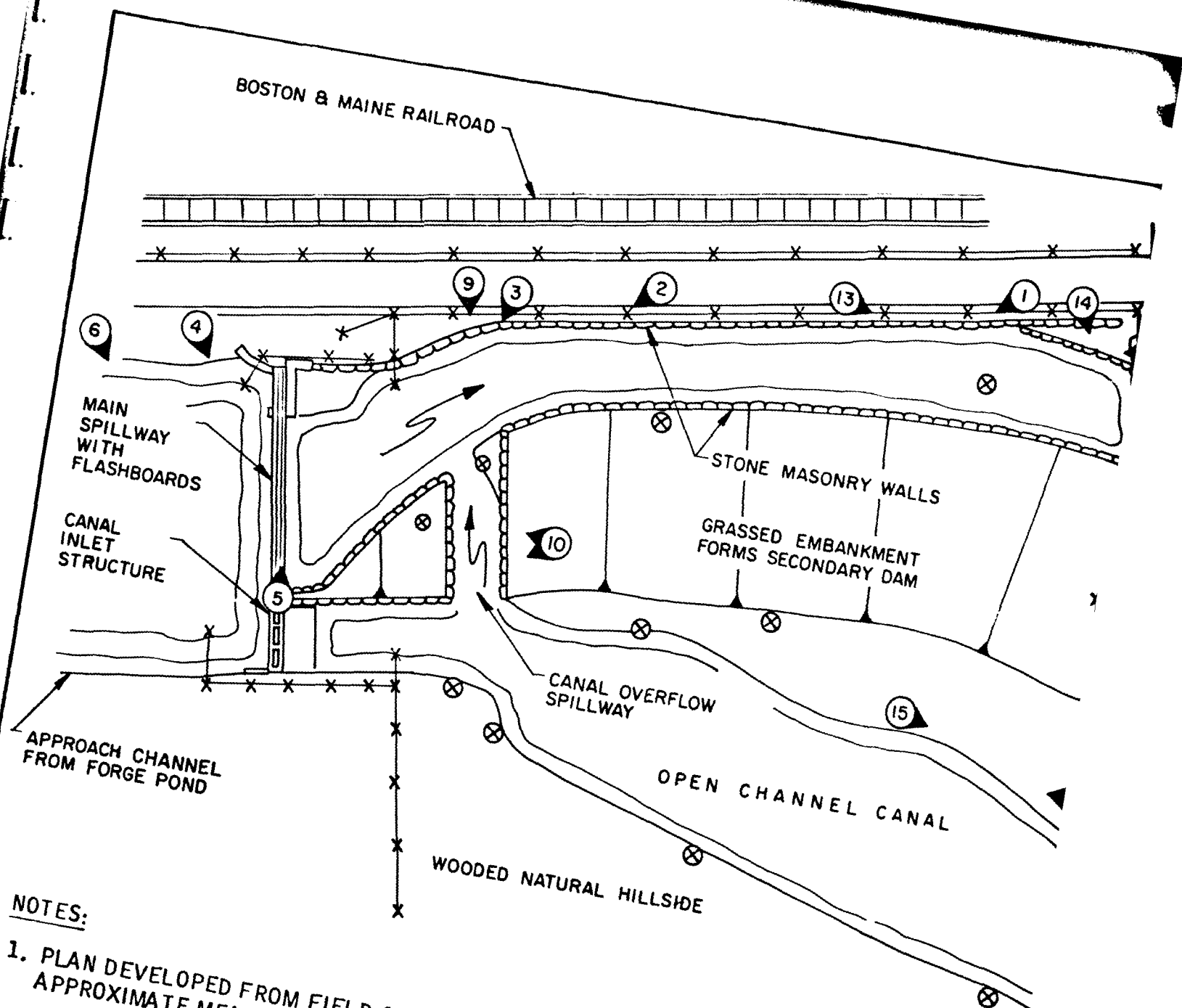
Site Plan Sketch

Page

C-1

PHOTOGRAPHS

<u>No.</u>	<u>Title</u>	<u>Roll</u>	<u>Frame</u>	<u>Page</u>
1.	Overview of Murray Printing Company Dam	C34	2	vi
2.	Main spillway structure	10	3	C-2
3.	Main spillway, apron and canal spillway exposed during period of lower flow (November 1978)	C31	7A	C-2
4.	Upstream side of dam	C34	24	C-3
5.	Left abutment of dam and walkway over main spillway	C34	12	C-3
6.	Gates on upstream side of canal inlet structure	10	6	C-4
7.	Canal excavated into hillside	C34	4	C-4
8.	Earth embankment separating canal and downstream channel	C34	3	C-5
9.	Ungated canal overflow spillway	10	4	C-5
10.	Approach channel and dam control structures	10	14,15	C-6
11.	Forge Pond reservoir area at entrance to dam approach channel	C34	25	C-7
12.	Downstream channel from main spillway to Pleasant Street	10	25	C-7
13.	Downstream channel culvert under Pleasant Street	10	7	C-8
14.	Embankment erosion at Pleasant Street culvert	10	22	C-8
15.	Canal and crest of embankment	C34	13	C-9
16.	Canal at cooling water and turbine intake	C34	16	C-9
17.	Downstream channel flow through buildings and plant complex	C34	20	C-10
18.	Parking lot on west bank where downstream channel discharges through twin culverts into Stony Brook	C34	22	C-10



NOTES:

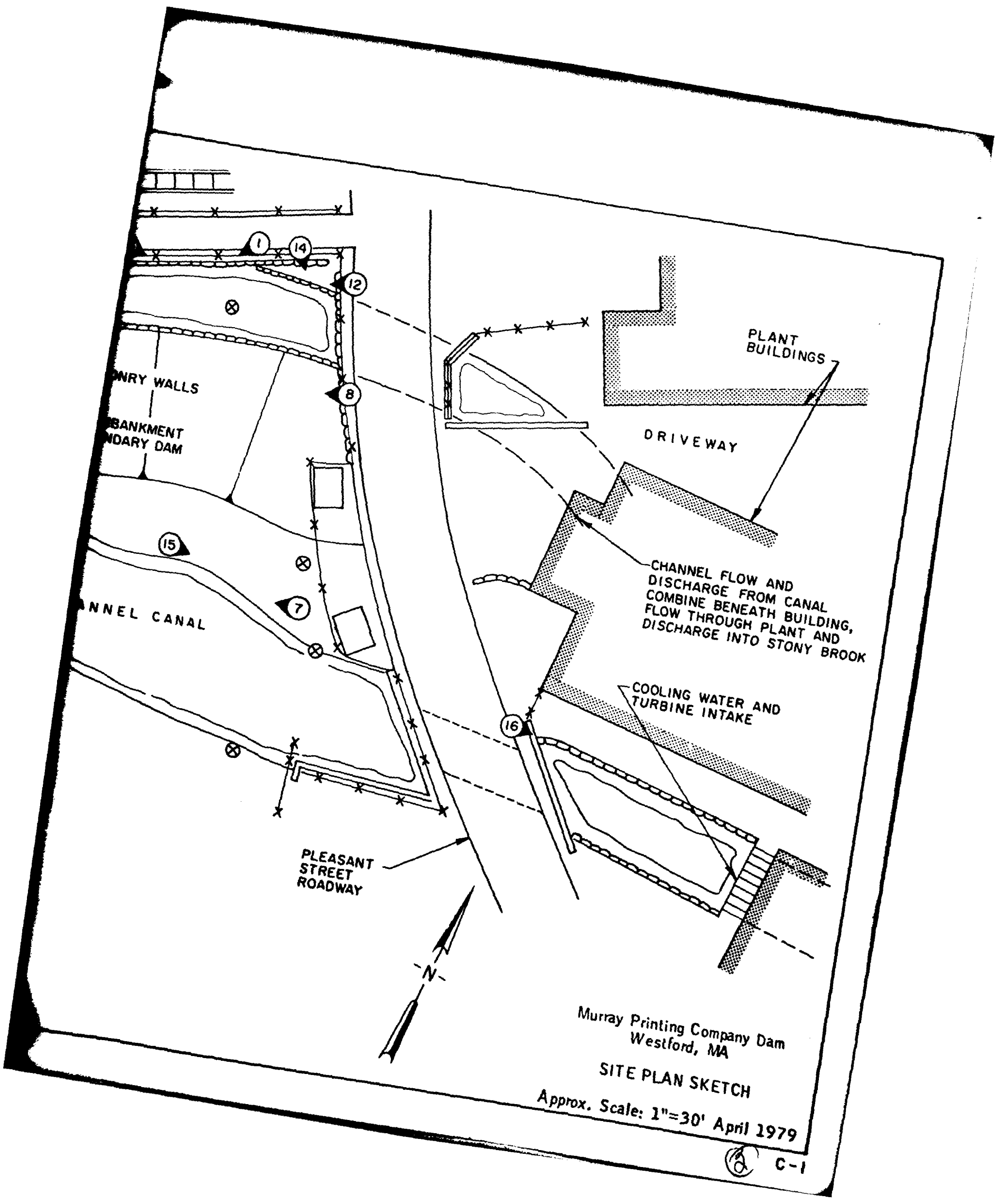
1. PLAN DEVELOPED FROM FIELD OBSERVATIONS AND APPROXIMATE MEASUREMENTS MADE ON 8 MARCH 1979.
2. PHOTOS NO. 11, 17 AND 18 TAKEN AT LOCATIONS BEYOND THE AREA SHOWN ON THIS PLAN.

LEGEND:

- ⑦ PHOTO NO. AND DIRECTION OF VIEW
- ⊗ TREE LOCATION

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

FILE NO. 4270 B33





2. Main spillway structure



3. Main spillway, apron and canal spillway exposed during period of lower flow (November 1978)



4. Upstream side of dam



5. Left abutment of dam and walkway over main spillway



6. Gates on upstream side of canal inlet structure



7. Canal excavated into hillside



8. Earth embankment separating canal and downstream channel



9. Ungated canal overflow spillway



10. Approach channel and dam control structures



11. Forge Pond reservoir at entrance to dam approach channel



12. Downstream channel from main spillway to Pleasant Street



13. Downstream channel culvert under Pleasant Street



14. Embankment erosion at Pleasant Street culvert



15. Canal and crest of embankment



16. Canal at cooling water and turbine intake



17. Downstream channel flow through buildings and plant complex



18. Parking lot on west bank where downstream channel discharges through twin culverts into Stony Brook

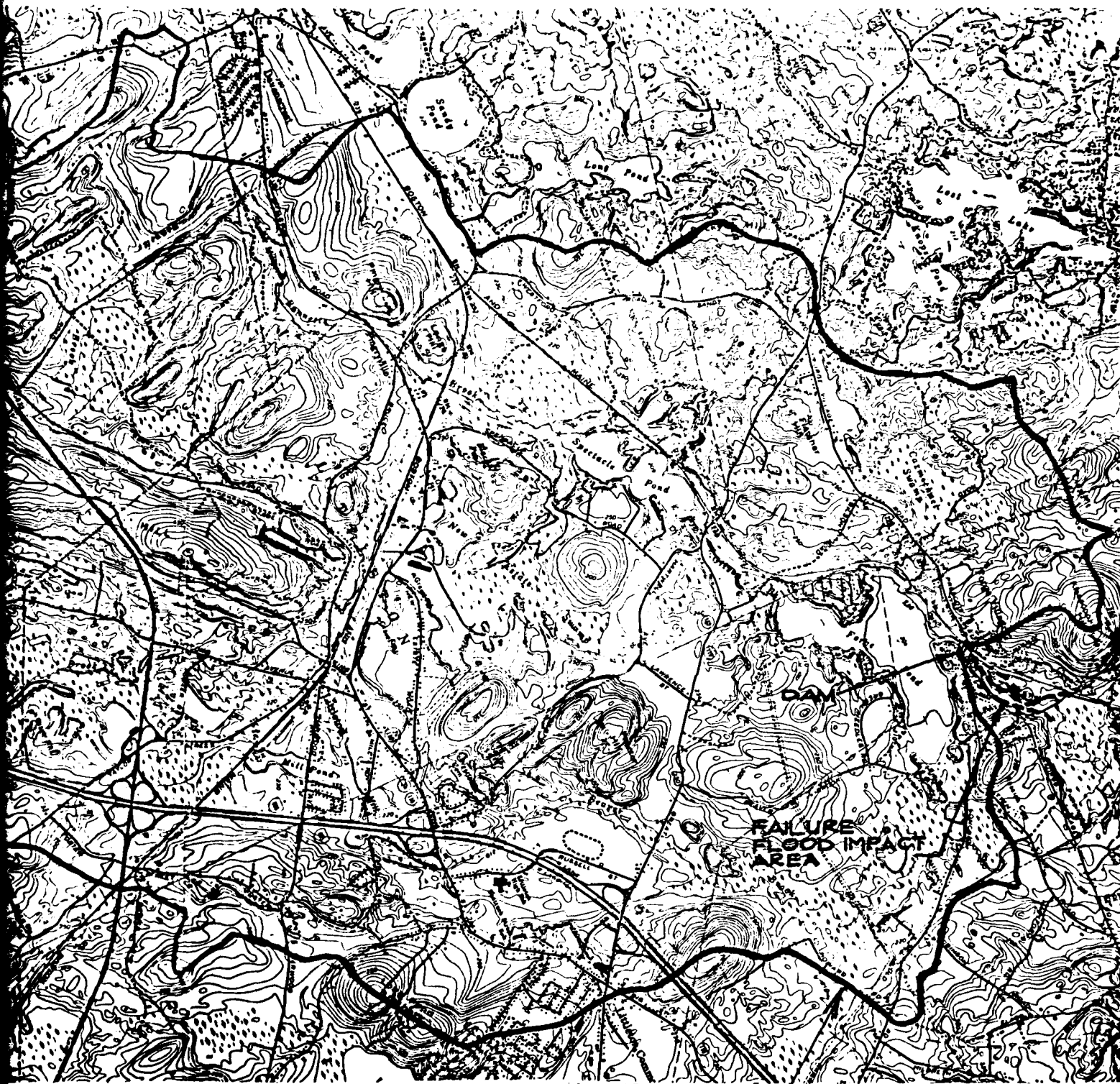
APPENDIX D - HYDROLOGIC AND HYDRAULIC COMPUTATIONS

	<u>Page</u>
<u>Computations</u>	
Drainage Area and Failure Flood Impact Area Map	D-1
Size Classification, Hazard Potential and Test Flood	D-2
Surcharge-Storage Routing	D-3
Stage-Discharge Curve at Dam Site	D-4
Stage-Discharge Curve at Saddle	D-5
Area-Volume Curve	D-6
Tailwater, Spillway Capacity	D-7
Stage-Discharge Curve; Downstream Channel	D-8
Dam Failure Analysis	D-9
Hydraulic Profile	D-10




①

CAMP DRESSER & McKEE Inc.
Consulting Engineers
Boston, Mass.



FAILURE
FLOOD IMPACT
AREA

APPARENT NATURAL
DIVERSION SADDLE (2)

<p>N</p> 	<p>MURRAY PRINTING CO. DAM DRAINAGE & FLOOD IMPACT AREA SCALE: 1:40,000 D-1</p>
---	---

CLIENT H & A JOB NO 561-9-RF-3 PAGE 1
PROJECT COE Dam Inspection DATE CHECKED 4/13/79 DATE 4/2/79
DETAIL Murray Printing Co. Dam CHECKED BY C.F. Fuller COMPUTED BY AMC

Size Classification

Height : $208 - 198.7 = 9.3 \text{ -ft} < 40 \text{ -ft}$

Storage : $2550 \text{ acre-feet @ El. } 208.0 > 1000 \text{ ac-ft}$

SIZE : INTERMEDIATE

Hazard Potential Classification

During a dam failure about seven buildings, including driveways and parking lots, within the Murray Printing Company compound are expected to be subject to flooding. The hazard potential is considered "SIGNIFICANT" because of potential for loss of few lives and excessive property damages.

Test Flood Development

Size : Intermediate ; Hazard : Significant

$Q_T = \frac{1}{2} \text{ PMF} \sim \text{PMF}$ use : $\frac{1}{2} \text{ PMF}$

Watershed : 23.8 sqmi. ; Terrain : rolling

Peak Flow Rate : $1,400 \text{ cfs/sqmi}$

PMF = $33,300 \text{ cfs}$

Test Flood Inflow : $16,650 \text{ cfs}$

CLIENT HWAJOB NO. 561-9-Rt-3PAGE 2PROJECT Dam InspectionDATE CHECKED 4/13/79DATE 4/8/79DETAIL Murray Printing Co. DamCHECKED BY C.E. FullerCOMPUTED BY ALLSurcharge - Storage Routing

$$Q_p = 16,650 \text{ cfs } (1/2 \text{ PMF} \rightarrow \text{Max Run-off} = 9.5")$$

Assume no flash boards. Spillway crest El. 204.0
 Some water would be diverted into the adjacent Nashua
 Brook basin through a saddle @ El. 205.0. The pond elevation at
 16,650 cfs discharge, therefore, was estimated by trial & error
 with utilization of stage - discharge curves in Pages D-4 and D-5;
 the resulting pond el. ≈ 218.00

The pond volume @ El. 218.00 = 15,200 ac-ft (See Page D-6.)

The normal Pond volume @ El. 204.0 = 624 "

Surcharge = 14,576 ac-ft

$$STOR_1 = \frac{14,576 \times 12}{15,230} = 11.45" \quad Q_{P_2} = 16,650 \left(1 - \frac{11.45}{9.5}\right) = 0 \text{ cfs}$$

$$STOR_{av} = 5.75" \quad Q_{P_3} = 16,650 \left(1 - \frac{5.75}{9.5}\right) = 6,576 \text{ cfs}$$

$$WSE \approx 212.8 \text{ (Saddle } Q \approx 4,200 \text{ cfs + Spillway } Q \approx 2,300 \text{ cfs)}$$

$$\text{Volume: } 7,050 \text{ ac-ft} \rightarrow \text{surcharge} = 6,426 \text{ ac-ft}$$

$$STOR_2 = \frac{6,426 \times 12}{15,280} = 5.04" \quad STOR_{av} = 5.4" \rightarrow Q_{P_3} = 7,200 \text{ cfs}$$

$$WSE = 213.2 \text{ (Saddle } Q = 4,600 \text{ cfs + Spillway } Q = 2,550 \text{ cfs)}$$

$$\text{Pond volume: } 7,600 \text{ ac-ft}$$

$$\text{Surcharge} \approx 7,000 "$$

$$STOR_3 = \frac{7,000 \times 12}{15,280} = 5.5" \approx 5.4" \quad Q_{outflow} = 7,200 \text{ cfs}$$

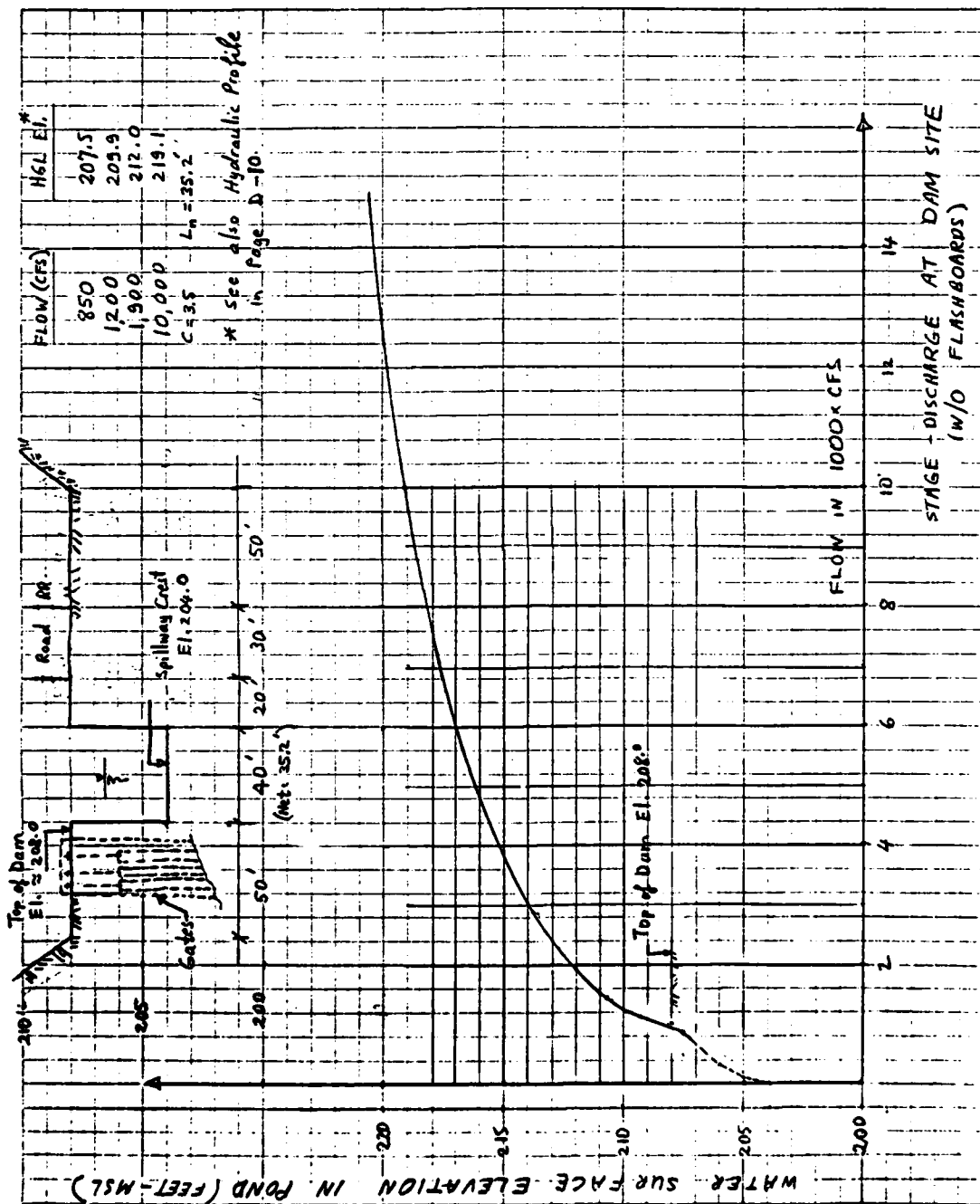
Summary:

TEST FLOOD OUTFLOW: 7200 cfs @ El. 213.2

(a) At Spillway: 2,550 cfs

(b) At Saddle: 4,650 cfs

CLIENT H & A JOB NO. 561-9-RT-3 PAGE 3
PROJECT Dam Inspection DATE CHECKED 4/13/79 DATE 4/8/79
DETAIL Murray Printing Co. Dam CHECKED BY C.E. Fuller COMPUTED BY AVG

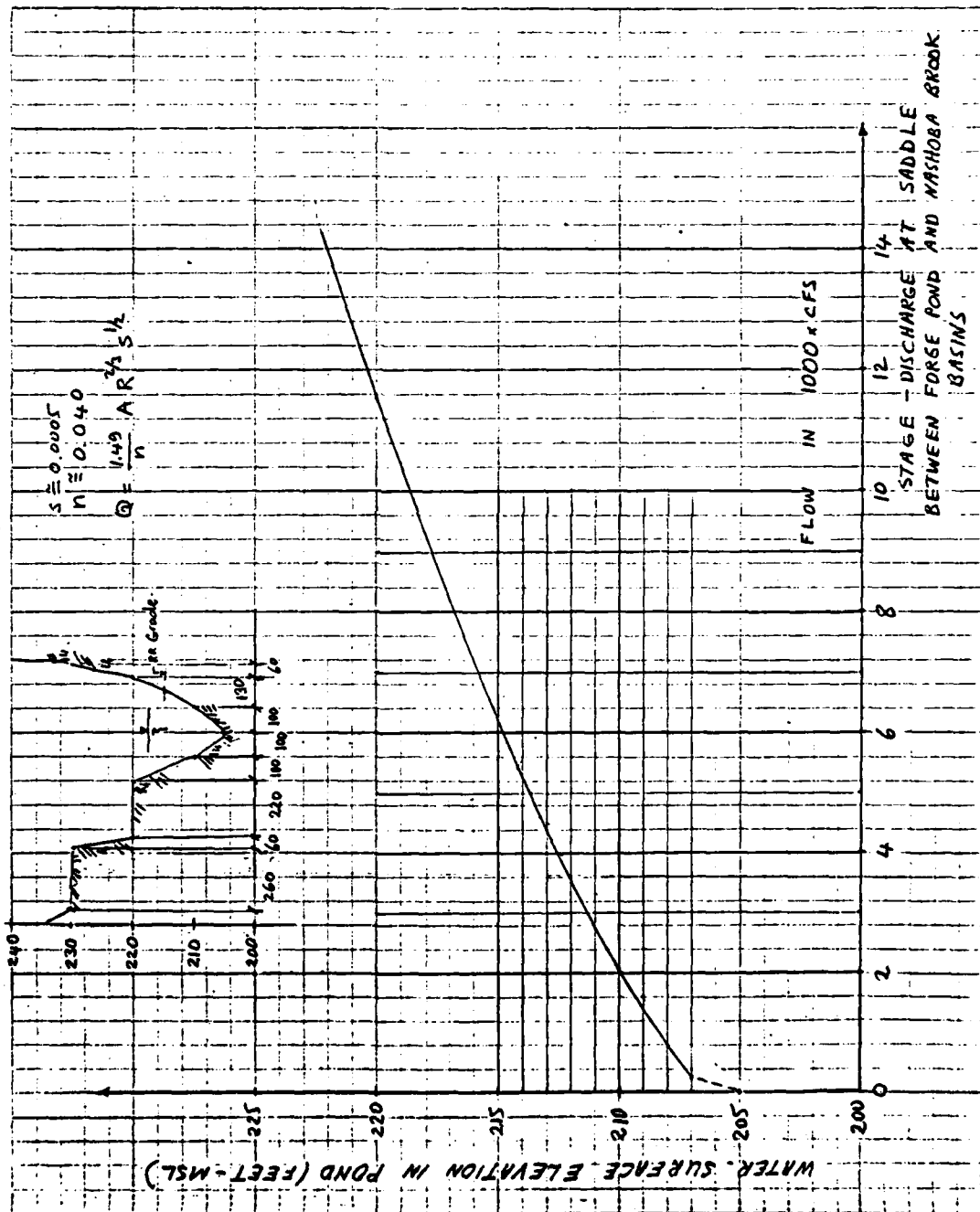


CAMP DRESSER & MCKEE
Environmental Engineers
Boston, Mass.

CLIENT HWA
PROJECT Dam Inspection
DETAIL Murray Printing Co. Dam

JOB NO. 561-9-Rt-3
DATE CHECKED 4/13/79
CHECKED BY G.E. Fuller

PAGE 4
DATE 4/8/79
COMPUTED BY ALL

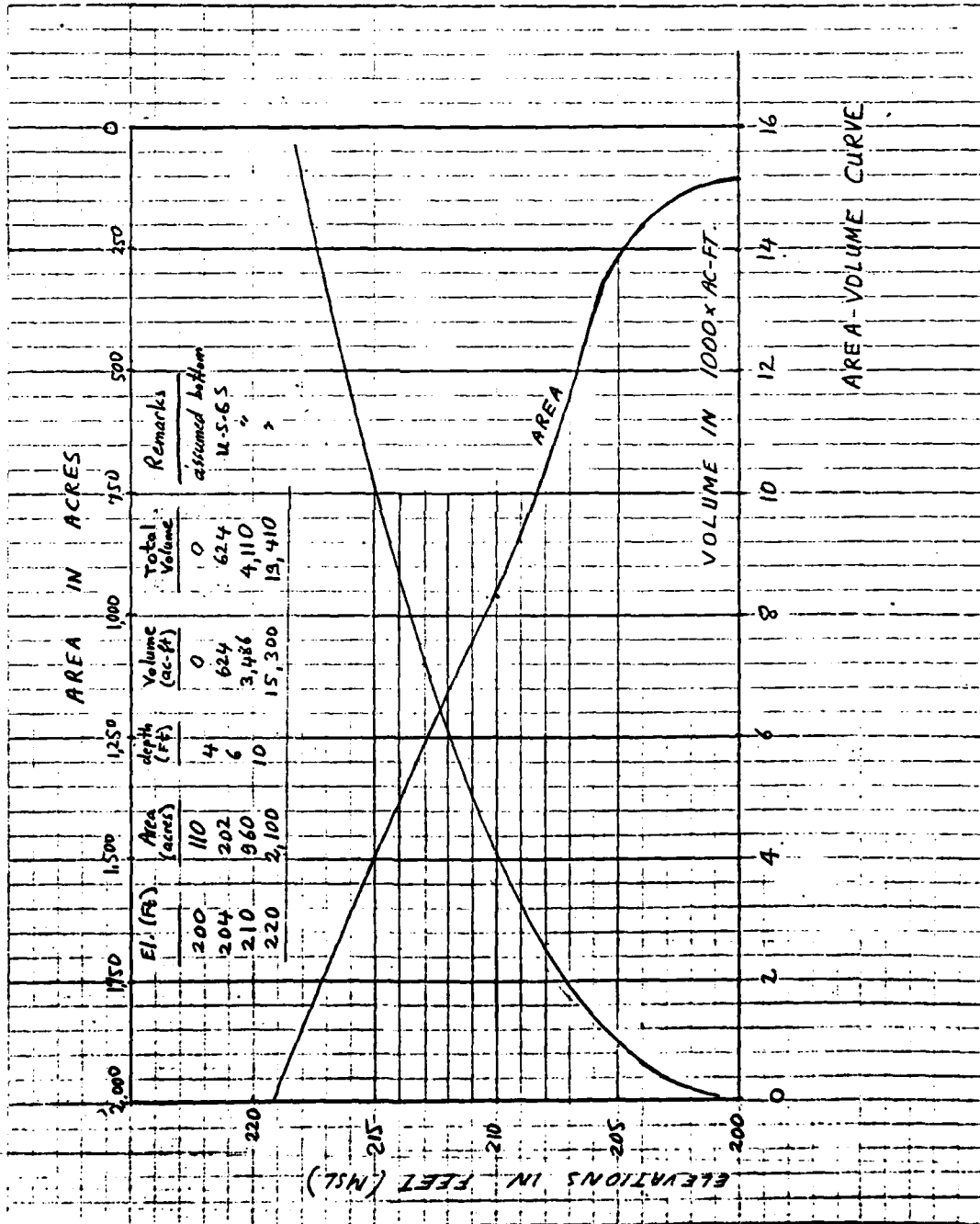


CAMP DRESSER & MOORE INC.

CLIENT: H & A
 PROJECT: Dam Inspection
 DETAIL: Murray Printing Co. Dam

JOB NO: 561-9-Rt-3
 DATE CHECKED: 4/2/79
 CHECKED BY: HUG

PAGE: 5
 DATE: 3/24/79
 COMPUTED BY: J.M./T.P.



CLIENT H. A.
 PROJECT CDE Dam Inspection
 DETAIL Murray Printing Co. Dam

 JOB NO 561-9-Rt-3
 DATE CHECKED 4/13/75
 CHECKED BY C.E. Fuller

 PAGE 6
 DATE 4/8/75
 COMPUTED BY RLG

Tail Water - Stage-discharge curve @ Spillway apron of the downstream channel, as shown in Page D-8, indicates that the spillway crest would be submerged by about 5.6 feet @ test flood outflow discharge of 2,550 cfs.

Spillway Capacity :

Main Spillway : $Q_m = 3.5 \times 35.2 (208 - 204)^{3/2} = 986 \text{ cfs}$
 (crest El. 204.0) @ Pond El. 208.0

Auxiliary Spillway : (If the gates at the river channel are open)
 (crest El. 205.8)

$Q_{aux} = 3.5 \times 12.7 \times 2.2^{3/2} = 145 \text{ cfs}$
 Total Spillway Capacity : $986 + 145 = 1,131 \text{ cfs}$ There would be no backflow effect from the downstream channel at this flow.

Spillway Capacity @ Test flood pool elevation of 213.2 (excluding flow over the banks) : $3.5 \times 35.2 (213.2 - 209.6)^{3/2} \approx 840 \text{ cfs}$ (Tailwater el. of 209.6 was obtained from the curve in Page D-8 for a total discharge of 2,550 cfs).

Check : how much the dam has to be raised to prevent bank overflow :

Try $Q = 1,600 \text{ cfs} \rightarrow H_{spill} = 5.5 \text{ ft.}$; Tailwater El. 208.6 @ $Q = 1,600 \text{ cfs}$

WSE in the pond : $208.6 + 5.5 = 214.1$

$Q_{saddle} = 5,400 \text{ cfs}$ $\leq Q = 7,000 \text{ cfs} \approx 7,200 \text{ cfs}$

If the height of the dam is raised by about 7-ft (from present elev. 208 to El. 215) a spillway discharge of 1,600 cfs would occur with a freeboard of .03-ft.

Conclusion The maximum capacity of the existing spillway at the Murray Printing Company Dam is limited to about 1,100 cfs, because of relatively short weir length and small amount of freeboard at the spillway crest for overflows.

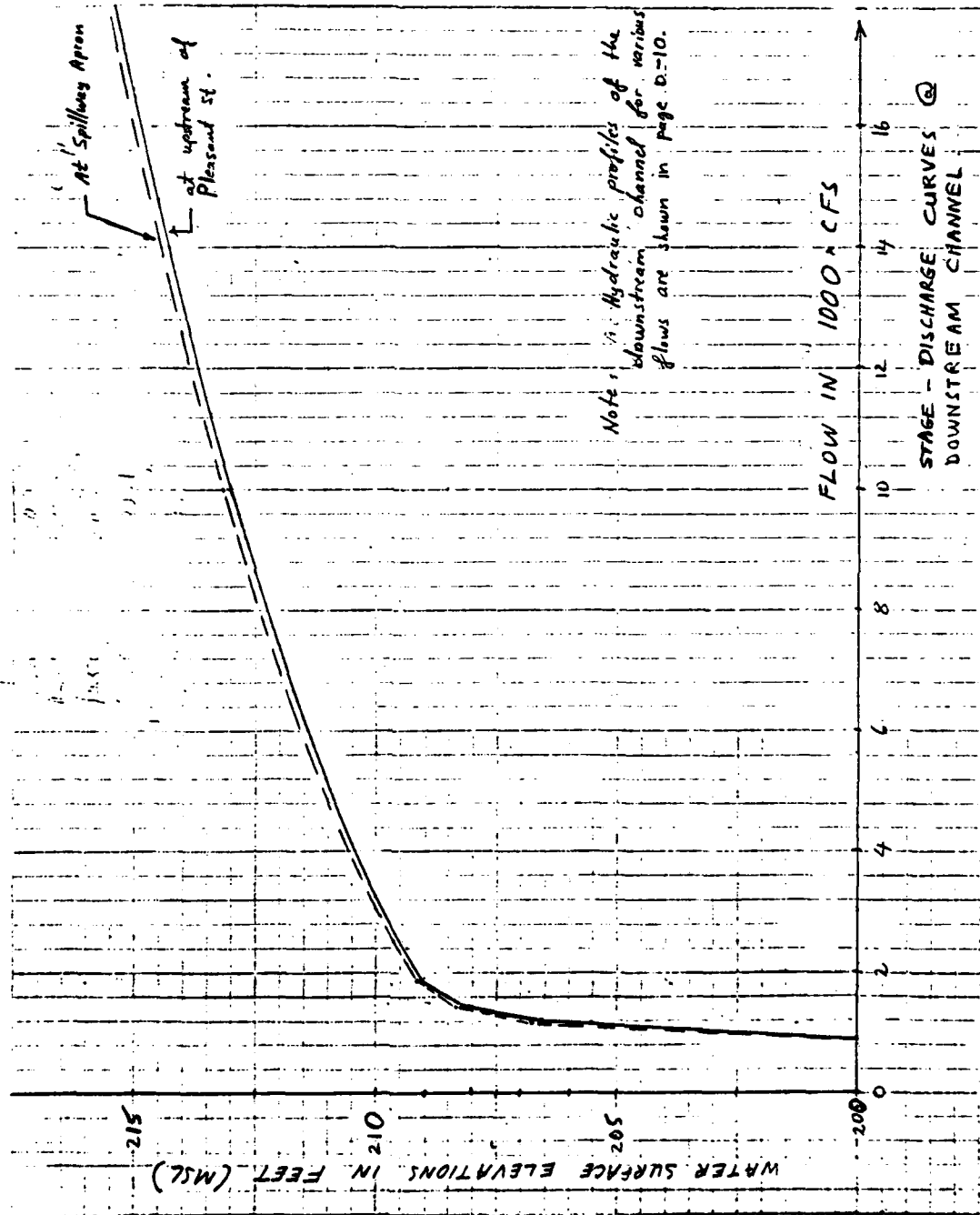
As shown above, the dam and the both banks are expected to be overtopped by about 5.6 feet of water during the test flood flow.

CAMP DRESSER & MORSE INC.

CLIENT H & A
 PROJECT Dam Inspection
 DETAIL Murray Printing Co. Dam

JOB NO 561-9-Rt-3
 DATE CHECKED 4/13/79
 CHECKED BY C. E. Fuller

PAGE 7
 DATE 4/8/79
 COMPUTED BY ALL



Dam Failure Analysis

$$\text{Failure Flood Flow: } Q_p = \frac{8}{27} W_b \sqrt{g} Y_o^{3/2}$$

$$\text{Assume } L = 76' \text{ (total length)} \quad W_b = 0.9 \times 76 = 68.4' \text{ (masonry dam)}$$

$$Y_o = 208.0 - 198.7 = 9.3' \quad Y_o^{3/2} = 28.4$$

$$Q_p = 2,950 \text{ cfs.}$$

$$\text{Storage @ El. } 208.0 = 2,550 \text{ ac-ft.}$$

An approximate and preliminary hydraulic profile along the downstream channel for the future flow of 2,950 cfs is shown in page D-10.

Two reaches were considered for flood flow routing.

Reach 1 : Dam to Pleasant St. : $V_1 = 4 \text{ ac-ft.}$ too small.

Reach 2 : Dam to the twin culverts (beginning of Story Brook) :

$$V_1 = 22 \text{ ac-ft.} \quad Q_{p2} = Q_p \left(1 - \frac{22}{2550}\right) = 0.99 Q_p$$

The effect of channel storage on the peak failure flow in the above reaches would be negligible as shown on the hydraulic profile next page. The both banks of the downstream channel would be flooded by about 7 feet of water. The flooding before the failure is estimated to be about 1-ft.

About 7 buildings, driveways and parking lots of the Murray Printing Co. are expected to be flooded in the event of a dam failure. Potential for loss of few lives and extensive industrial property damages would put this dam under "significant" hazard classification.

Note For the dam safety investigation, it is assumed that a failure would occur only at the dam which is under study and the other upstream and downstream facilities, such as dams and bridges, would remain intact; for example, we have not considered the effects on the dam under study, which could be caused by failure of an upstream dam, especially a larger upstream dam.

CAMP DRESSER & MOORE INC.

CLIENT HALEY AND ALDRICH

JOB NO 561-9-RT-3

PAGE 11

PROJECT DAM INSPECTION

DATE CHECKED 4/9/79

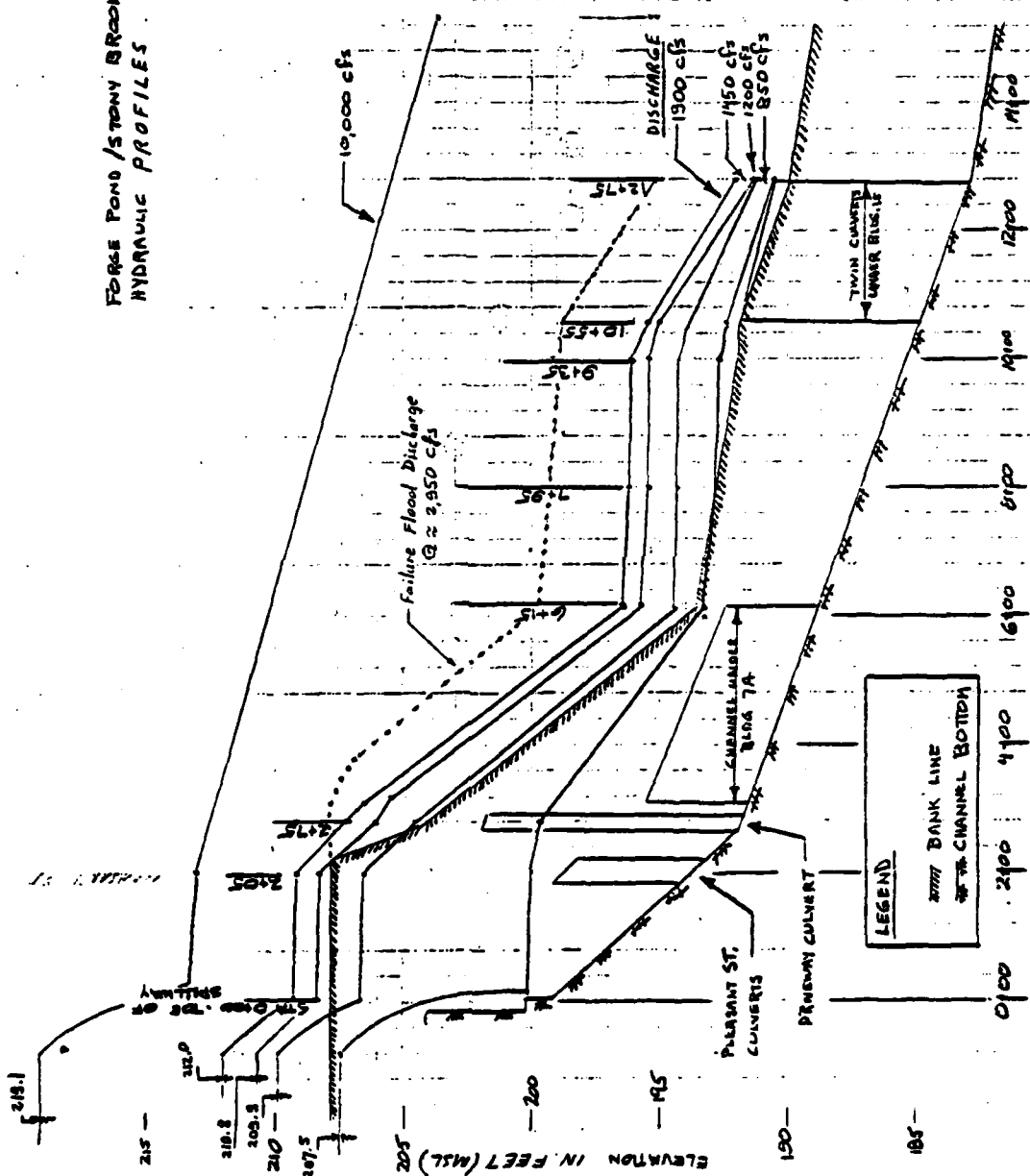
DATE 4/9/79

DETAIL MURRAY PRINTING Co. DAY

CHECKED BY ALG

COMPUTED BY JCF

FORCE POND / STONY BROOK
HYDRAULIC PROFILES



**APPENDIX E - INFORMATION AS CONTAINED IN
THE NATIONAL INVENTORY OF DAMS**